# Role of Conservation Tillage in Sustainable Agriculture

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Conservation tillage management can reduce soil erosion, enhance soil productivity, decrease dependency on fossil fuels and minimize water, nutrient, and pesticide runoff. It is my hypothesis that no-till management is necessary for sustainable crop agriculture. The objective of this paper is to outline the benefits of no-tillage in light of sustainability.

## Soil Erosion Control

Crop residue on the soil surface is one of the most effective means of controlling soil erosion, and no-tillage management is an effective means of maintaining ground cover by crop residues. The landmark paper by Beale et al., (1955) was one of the first to demonstrate the importance of reduced tillage in controlling soil erosion. As equipment and chemical weed control practices were developed, no-tillage production became possible. Subsequent work by McGregor et al., (1975), Triplett and Van Doren (1977), and Langdale et al., (1978) showed that no-tillage with complete groundcover reduced soil erosion to less than T and in some cases to almost nothing. Data from Langdale and Leonard (1983), shown in Table 1, illustrate the erosion control afforded by no-tillage.

**Table 1. Effect of tillage on runoff and soil loss in individual storms during high-energy rainfall months**

| Date | Rainfall (in.) | Rainfall Energy (lb-a/ft$^2$) | Runoff (in.) | Soil Loss (t/a) |
|---|---|---|---|---|
| | | Conventional Tillage | | |
| May 28, 1973 | 3.9 | 7.18 | 2.0 | 7.8 |
| June 06, 1973 | 1.5 | 3.49 | 0.8 | 6.0 |
| July 30, 1973 | 1.1 | 3.02 | 0.5 | 0.7 |
| | | No-tillage | | |
| June 11, 1975 | 1.9 | 7.24 | 1.0 | <0.01 |
| July 13, 1975 | 1.0 | 2.82 | <0.1 | <0.01 |
| July 24, 1975 | 1.7 | 2.68 | <0.1 | <0.01 |

Erosion has both on-site and off-site impacts. The on-site impact is rcduced productivity, while the off-site impact is degraded water quality as a result of scdimcnt loading and associated nutrients and pesticides. However, no-tillage can halt the deterioration of the soil by erosion. Furthermore, there is evidence that no-tillage can even reverse the deterioration and help restore productivity on eroded soils (Langdale et al., 1987). The significance of this to sustainability is obvious.

## Soil Improvement

An important benefit of no-till production is grcatcr soil organic matter concentrations, especially near the soil surface (Blcvins et al., 1983; Dick, 1983; Hargrove et al., 1982; Lal et al., 1980). Our results in Georgia have shown that soil organic matter accumulation is significant with no-till management, and the degree of accumulation dcpcnds largely on the amount of organic C returned to the soil (Table 2).

**Table 2. Influence of 5 years of various cropping sequences and tillage on soil organic C and N concentrations in the surface 3 in. of soil (from Hargrove and Frye, 1987).**

| Crop Sequence | Tillage | Organic C % | Organic N % |
|---|---|---|---|
| Wheat-Soybean | Conventional | 1.4 | 0.12 |
| Wheal-Soybean | No-till | 1.6 | 0.15 |
| Clover-Sorghum | No-till | 2.2 | 0.17 |

**Soil Water Relations.** The benefits of no-tillage with respect to improved soil water relations have been well documented (Blevins et al., 1971; Triplett et al., 1968; NeSmith et al., 1987). The improvement in soil water relations afforded by no-tillage is generally by virtue of soil surface mulch cover. Mulch cover generally increases water infiltration and/or decreases evaporation from the soil surface. Results obtained in Georgia using a sprinkling rate of 1.5-in per hr, showcd the mean final infiltration rate after 60 min of sprinkling was 1.4-in per hr for the no-till soil compared to 0.6-in per hr for the plowed soil. It was subsequently determined that the greater infiltration rate of the no-till soil was primarily a result of surface cover which intercepted the raindrops and preventcd the crust formation which occurred on the bare soil.

The net effect of improved water infiltration and decreased evaporation is greater amount of soil water available for plant growth. This improved soil water

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availability has been well documented in Georgia, and has generally resulted in greater plant growth and crop yields (Hargrove and Hardcastle, 1984; Hargrove, 1985; NeSmith et al., 1987).

**Soil Biological Activity.** No-tillage results in an increase in soil biological activity, especially near the soil surface. Doran and co-workers (Doran, 1980a, 1980b; Broder et al., 1984) have shown that maintenance of crop residues on the soil surface generally results in increascd populations and activity of most soil microorganisms in the surface 10 cm of soil. The effcct of soil disturbance on levels of microbial biomass, soil water content, and organic matter in surface soil is shown in Table 3. As soil disturbance increased, the amount of microbial biomass decreased. The reason for this is the combined effects of the concentration of organic substrate near the soil surface and the bcttcr environment, in terms of moisture and temperature, for microbial growth. More recently, Power ct al., (1986) showed that one of the results of the increased microbial activity near the soil surface of undisturbed, mulched soils was increased mineralization, availability, and crop utake of indigenous soil N.

**Table 3. Effect of degree of soil disturbance on levels of microbial biomass, water content, and organic matter of the surface 3 in. of soil (taken from Power and Doran, 1984).**

| Management | Degree of Disturbance | Microbial Biomass lb C/a | Volumetric Water Content % | Organic Matter % |
|---|---|---|---|---|
| Sod | None | 955 | 17.7 | 4.49 |
| No-till | Minimum | 790 | 14.3 | 3.80 |
| Subtillage | Moderate | 739 | 12.1 | 3.28 |
| Plow | Maximum | 587 | 10.6 | 2.42 |

In addition to the increase in soil microbial biomass, it has been demonstrated that earthworm populations increase with no-tillage compared to conventional tillage (Edwards, 1975; Edwards and Lofty, 1980; House and Parmelee, 1985). In long-term tillage plots in Georgia, we have observed as many as 50 earthworms square yard in the surface 6-in of soil with continuous no-tillage compared to 0 earthworms in a plowed soil. This increase in earthworm activity results in increased soil burrows and macroporosity (Edwards, 1975; Edwards and Lofty, 1980), which, in turn, promotes good soil aeration and root growth. In fact, we have obscrvcd root growth using minirhizotrons in our long-tcrm, no-till plots and found that relative root growth is grcatcr for long-term no-till managcmcnt compared to a plowcd soil (Hargrove, 1985; Hargrove et al., 1988a; Hargrove et al., (1988b).

**Soil Aggregation and Macroporosity.** The effect of increased organic matter and biological activity is improved soil physical condition including increased aggregate stability and macroporosity. Research in the 1940's and 1950's documented improved soil tilth, aggregate stability, and soil macroporosity with increases in soil organic matter (Lutz, 1954; Pieters et al., 1950; Uhland, 1949; and Welch et al., 1950). Allison (1968) found that returning crop residues to the soil improved aggregation chiefly by furnishing a carbon source for microorganisms which produce mucus and other binding agents. This is particularly important with no-tillage as crop residues and soil microbial activity are concentrated near the soil surface. The potential for improved aggregate stability near the soil surface is therefore great. Results from aggregate stability measurements in experiments conducted in Georgia are shown in Table 4. Although tillage was not a variable in this experiment, the data show that aggregate stability increased as the amount of organic matter returned to the soil surface increased. Tillage would not only destroy aggregates, but would dilute the effcct of residues.

**Table 4. Influence of cover crops on soil aggregate stability after 3-yrs of no-till sorghum production.**

| Cover crop | Annual C Input from Cover crop lb/a | Soil Organic Carbon % | Water-Stable Aggregates % |
|---|---|---|---|
| None | | 0.85b | 28.9b |
| Wheat | 812 | 0.89b | 32.6ab |
| Hairy Vetch | 1103 | 1.02a | 36.7a |

Macropores are important to soil aeration and root growth. Wc have demonstrated that although no-tillage can result in compacted soil horizons, macropores can allow root growth through these horizons (Hargrove et al., 1988a,b).

## Reduced Fossil Fuel Use

No-tillage has a much lower fuel requirement because primary and secondary tillage operations are eliminated. For a moldboard plow/disk tillage system, this would eliminate about 4 gallons of diesel fuel per acre per year, a significant energy savings.

In addition, the use of a legume cover crop to replace some of the fertilizer-N requirement along with no-till management could reduce the total fossil fuel requirement by as much as 27% (Neely et al., 1987). This would have both a significant economic and environmental impact.

**Crop Growth and Yield With Long-Term No-Till Management**

The net effect of improved soil erosion control, increased soil organic matter, increased water availability, increased biological activity, and soil structure is improved crop growth and yield. Many published studies have shown a yield increase from no-till management (Adams et al., 1973; Van Doren et al., 1976; Langdale et al., 1984; Beale and Langdale, 1967; Campbell et al., 1984; Griffith et al., 1973; and NeSmith et al., 1987; Hargrove, 1985). Generally, yield responses in short-term (<5 yrs) experiments occur in years when significant moisture stress also occurs and are due to increased soil water supply afforded by the surface mulch. The other benefits of no-till management with respect to erosion control and soil improvement are more long-term in nature and are poorly documented in the literature.

In Georgia, we have been comparing no-tillage to moldboard plowing in a field experiment over a thirteen-year period. Relative crop yields from this experiment are shown in Fig. 1. No-till yields were significantly greater than conventional tillage in seven years (1979, 1981, 1983, 1985, 1986, 1987, 1988), but the same in three years (1976, 1982, 1984). The three years in which equal yields were obtained were years with good rainfall distribution. In one year, no-tillage resulted in significantly lcss yield due to failure to get a plant stand with the no-till treatments. The mean ratio of yield for no-tillage compared to conventional tillage was 1.40. These results indicate that no-tillage through improved crop productivity can play a significant role in a sustainable agriculture.

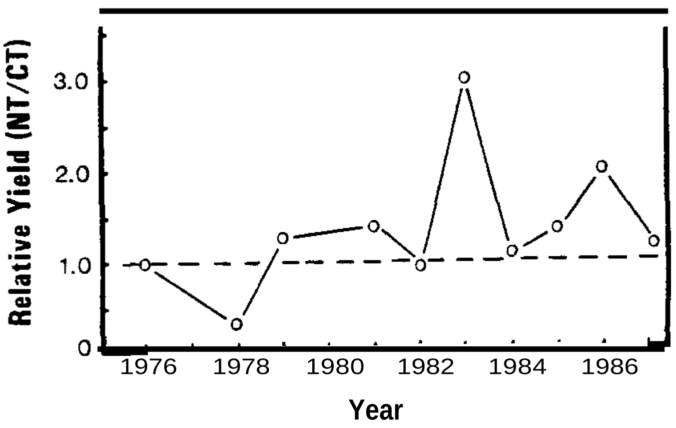


**Figure 1.**

## Conclusions

The beneficial effects of no-till management include the following:

1) soil erosion control, which will both maintain soil productivity and lessen off-site environmental damage,

2) Soil improvement including

   a) soil organic matter maintenance or even enhancement
   b) reduced water runoff and improved soil water storage
   c) improved soil biological activity
   d) improved soil structure, aggregate stability, and macroporosity,

3) Lessened dependence on fossil fuel energy,

4) Improved crop growth and yield.

These benefits form a core of criteria which need to be met in order to achieve a sustainable crop agriculture. The importance, then, of no-till management to the development of sustainable crop production systems is self-evident. We conclude that no-till management forms the fundamental foundation of a long-term strategy for crop production and should play a key role in the development of a sustainable crop agriculture.

A challenge facing agricultural scientists and conservationists is to develop strategies for no-till production with reduced dependence on pesticides and other chemicals. Practices and innovations which might make this integration possible include, 1) improved crop pest resistance and nutrient utilization through plant breeding and biotechnological advances, 2) improved crop management in terms of diversification and crop rotation, 3) judicious use of pesticides, and 4) maintenance of mulch on the soil surface.

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